

# A Review on the State of Art of Smart Material for Defence Applications

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## ABSTRACT

Smart materials are nowadays used in all spheres of life. The change in technology and development in the research field has lead smart materials to play a vital role in human life. Smart materials can adjust themselves according to the surroundings and change their properties in response to the stimulus input. However, the demand for smart materials has been increased in defense, automotive, and other industrial branches. These smart materials are listed under the group of advanced materials. A different application of smart materials can be used in industrial applications, aviation, etc. The use of smart materials in defence applications has been discussed below.

**KEYWORDS:** Smart material, shape memory alloy, piezoelectric material, defence, aviation

**How to cite this paper:** Hrutuja A. Madake | Younus A. Fakir | Santosh S. Bhanuse | Chinmaya R. Shinagare | Khalid S. Pirjade | Avesahemad S N Husainy "A Review on the State of Art of Smart Material for Defence Applications"

Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-5 | Issue-4, June 2021, pp.1448-1453,

URL: [www.ijtsrd.com/papers/ijtsrd42589.pdf](http://www.ijtsrd.com/papers/ijtsrd42589.pdf)



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## INTRODUCTION

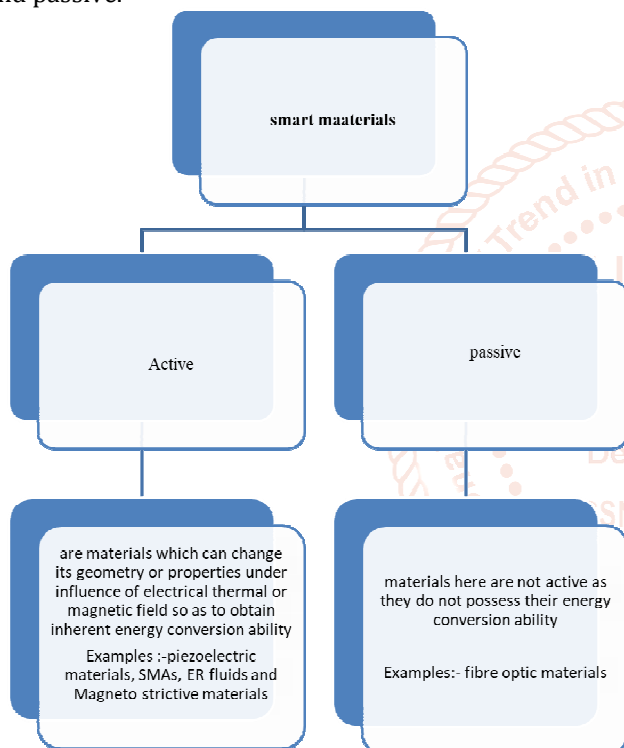
Human being from thousand years ago used material for different purposes, which enhanced their life styles, even civilization was classified by different ages that started by discovering a new effective material. According to archaeologists, the first age belongs to Stone Age, and a most revolutionary fall out with discovery of bronze, because it was harder and durable than the other on hand materials. The Bronze Age was the beginning of metallurgy, which civilization steps further to extract different materials [1]. Heading towards 20<sup>th</sup> and 21<sup>st</sup> century, with development in technology Smart Materials came into lime light. Smart Materials are designed materials that have one or more properties that can be significantly changed in a controlled fashion by external stimuli, such as stress, moisture, electric or magnetic fields, light, temperature, pH, or chemical compounds. These materials have a wide range of application including sensors and actuators, or artificial muscles. Smart materials gained its relevance due to its versatility and not just because of its noteworthy properties. Here versatility is related to consciously adding purpose to materials, to include some features such as self-repair for improvement of concluding performance of the system. It is made distinct from traditional systems by growing a degree of integration with material itself. Versatility is the key in

these materials. In metal substances versatility is gained through adding practicality at surface as is that in case with heat insulation it is the concept that has been most fully explored with composite materials, since the incorporation of the additional functionality is most easily realized in these materials because of relatively low processing temperatures and benign manufacturing process used in production [2].

Technology is becoming pervasive in our daily lives, altering the needs of modern existence in a variety of ways. Smart materials must actively react with different environmental modifications so as to function accordingly. Nowadays these materials are preferred to cope with different problems related with aerospace, mechanics, bionics and medical technologies. Further smart materials are classified into 4 different types namely, metals, ceramics, polymers, and recently advanced materials. Shape Memory Materials (SMM), such as shape memory alloys, Shape Memory polymers, and Shape Memory Composites, are the most prominent. As smart materials are light weighted, compact in size, flexible and functional; these smart materials have a wide range of application. They can be used in aviation industries, the Defence Advanced Research Projects Agency (DARPA), fibreoptics, vibration control, etc. As some physical

properties of advanced materials can be controlled; they are the building block of the most advanced hybrid devices around us. By changing their properties, smart materials can detect faults and cracks and thus are useful as a diagnostic tool, this characteristic can be utilized to active the smart materials embedded in the host material in proper way to compensate for the fault and this is self-repairing phenomenon [3]. Smart materials can be prominently used in defence applications. Nanotechnologies promise modern technological modifications for a huge variety of navy programs and platforms. With increase in population, the use of Air transport has been increased simultaneously. To fulfill the need of passengers there is a need of advance technology considering the factor of our safety. These days numerous kinds of materials are utilized in aviation ventures however the smart materials are acquiring significance persistently due to their improvement reactions and remarkable highlights.

Smart materials are broadly classified into 2 types, active and passive.

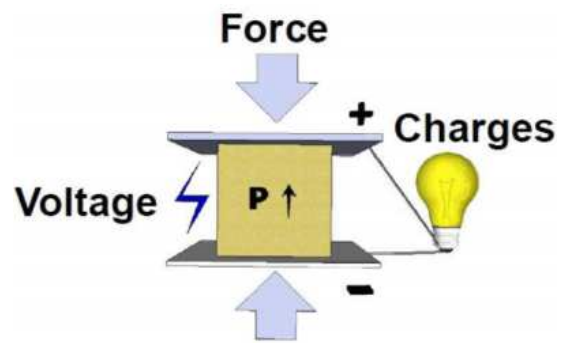


**Smart materials are classified as:**

1. Piezoelectric materials
2. Electrostrictive materials
3. Magnetostrictive materials
4. Rheological materials
5. Thermo-responsive material
6. Electrochromic materials
7. Fullerenes
8. Biomimetic materials
9. Smart gels

#### 1. Piezoelectric material:

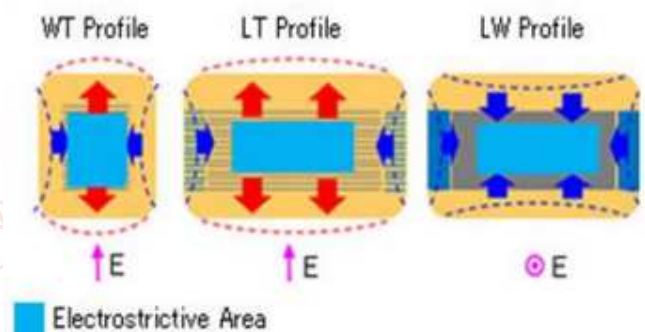
When this material is exposed to current or flow of electron they undergo mechanical changes like (shape, properties, etc).when they deformed voltage is generated. There are a few materials that we have known for quite a while that groups piezoelectric properties, including bone, proteins, precious stones (for example quartz) and ceramics (for example lead zirconatetitanate). Piezoelectricity will become another weapon which we can use to reduce our reliance on fossil fuels and to derive the energy we need.



**Fig. a): Piezoelectric Materials [4]**

#### 2. Electrostrictive material:

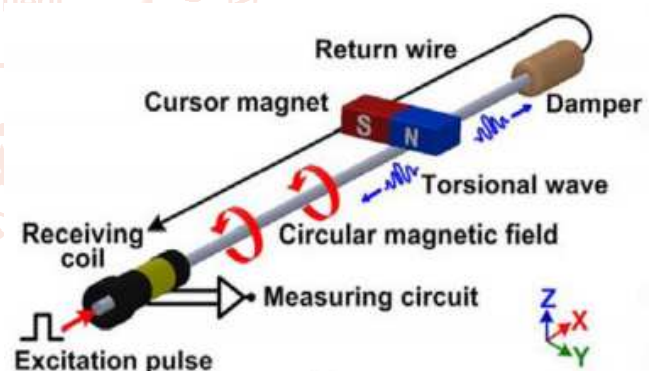
They are similar to piezoelectric material and the mechanical change like (shape, properties, etc).are square of its electric field.



**Fig. b): Electrostrictive material [4]**

#### 3. Magnetostrictive materials:

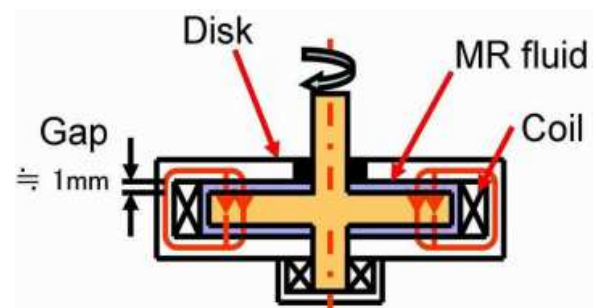
This material are consist of small ferromagnetic substance. These ferromagnetic substances are mainly cobalt, iron or nickel. When they are subjected to magnetic field mechanical strain induced in the material.



**Fig. c): Magnetostrictive materials [4]**

#### 4. Rheological materials:

These types of material are in liquid phase. They can change phase when they are exposed to electric or magnetic field and they react to only these two fields. Rheological materials never change its phase to gas. They can also react when there is an impurity and there is a low volt supply.



**Fig. d): Rheological materials [4]**

## 5. Thermo-responsive material:

Thermo-responsive materials are the materials which change their properties according to the change in temperature. They are mostly used in thermometer and parts of vehicles. They are also called temperature responsive materials.

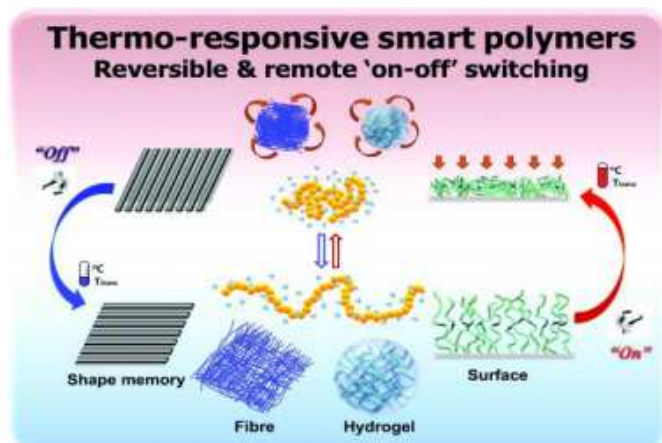


Fig. e): Thermo-responsive material [4]

## 6. Electrochromic materials:

When voltage is applied to the material. Material undergoes change in optical property. They are widely used in LCD's, Monitor etc. Displays are based on the material which changes their color depending on applied potential.



Fig. f.1): Electrochromic Virtual Window Blind [4]

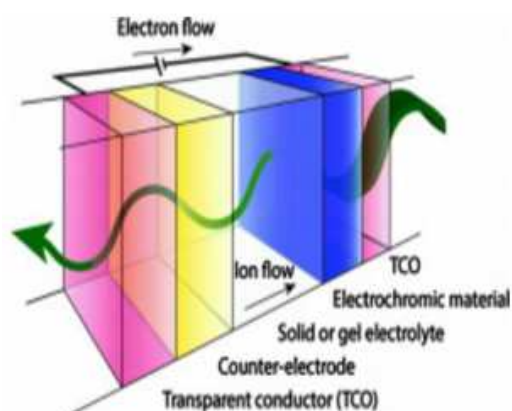


Fig. f.2): Electrochromic on an Aircraft Cabin Window Device [4]

## 7. Fullerenes:

These are the spherically closed molecules made up of pentagon and hexagon like structure. This has 60 atoms of carbon in it or Buckminsterfullerene which has twenty hexagons and 12 pentagons like structure in it.

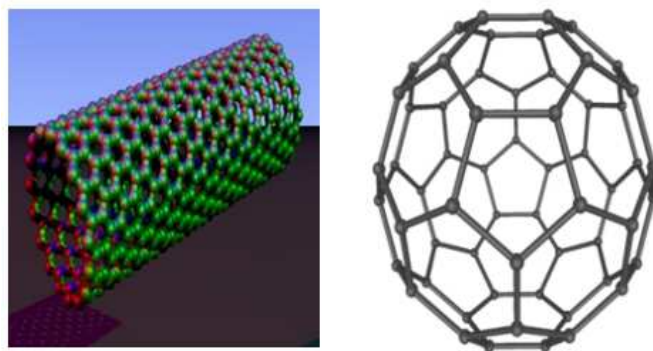


Fig. g): Fullerenes [4]

## 8. Biomimetic materials:

These materials are sometimes useful in design of composite materials and are inspired from the nature. Examples of natural structure are honeycomb structure of the beehive, strength of spider silks etc.

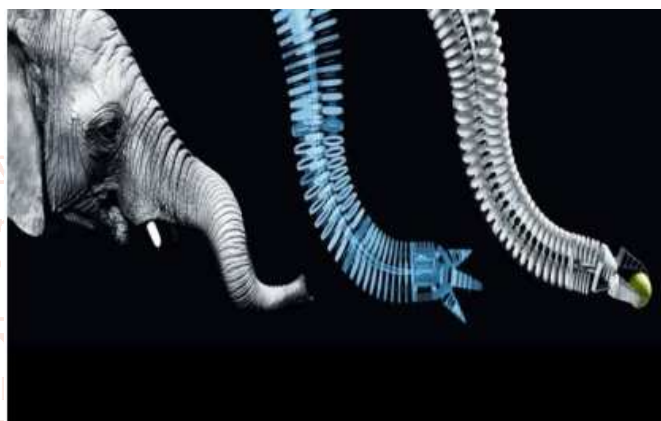


Fig. h): Biomimetic materials [4]

## 9. Smart gels:

It is a jelly like material which has properties like soft, weak, hard and tough. They are mostly liquid but they look like solid due to linking of bond with the liquid molecules. Where adhesive force is acted.



Fig. i): Smart gels [4]

## Applications of Smart materials:

1. Danger reduction
2. Self repair
3. Defence and space
4. In nuclear industries
5. In structural engineering
6. In biomedical applications
7. For reducing waste
8. Health
9. Helping Ageing population



**Shape Memory Alloys:**

With development in technology, shape memory alloys have gained high importance in Aviation and Defence. Shape-memory composites are metals that, regardless of whether they become disfigured at under a given temperature, they will get back to their unique shape before distortion just by being warmed. Composites with this uncommon trademark are utilized as utilitarian materials in temperature sensors, actuators, and clipping installations. These materials possess properties like super-elasticity; like rubber, when it is bent or stretched, it will return to its original shape when the deforming force is removed. This property of forming in spite of severe deformation is used in applications in everyday products, in electrical and electronic devices and in the medical field. SMAs also display super-elasticity that is a mechanical type of shape memory. This effect is observed when alloys are strained just above their transformation temperature.

**In Defence Applications:**

Technology can play a significant role in helping to protect soldiers, and providing solutions to adapt personal protective equipment to meet the changing demands of modern warfare. Smart materials have property of self-repairing, which can be used in combat shirts and pants. Soldiers can use smart shirts made of special tactile material that can detect a variety of signals from the human body, such as detection of hits by bullets. It can generate signal which can indicate nature of injuries, analyze their extent, etc. Smart materials can be used in a wide range of domains and hostile environments where risks and damages can be reduced with the use of protective solutions. Other potential applications of advanced materials to be explored in the future include the potential of self-healing materials, cyber-protective materials, biomimetic material design, etc.

**Literature Survey:**

According to **R.V. Kurahatti** et.al the potential opportunities enabled to advance in defence technology through nanotechnology are amazing. Although these opportunities have been realized over the decades, there are many benefits currently being explored, especially for defence applications. This review provides an insight into the capabilities offered by Nano composites which include smart materials, harder/lighter platforms, new fuel sources and storage as well as novel medical applications. With only moderate success in the last 20 years, researchers need to examine strategies to achieve improved mechanical and transport properties to optimize the fabrication of nanotube-enabled materials. Dedicated efforts are required in areas such as signature management. The two major emphasis areas in defence are the use of Nanocomposites in large-scale integrated multifunctional materials for UAVs and materials that increase efficiency and the survival of independent soldiers.[5]

**Lloyd et.al** talks about planned creation of multifunctionality which aids the particular features of smart substances. Thus introduction of multifunctionality can enable the material, or the structure from which it is made, to diagnose its conditions or environment, change shape, self-repair or other functions as developing technology allows. Author says that in more and more applications, smart materials can be used to enhance practicality of materials utilized in aerospace structure. Constant demand for efficiency improvements related to energy or quality or both has driven the effective implications of new functions.

Unless and until being the part of system wide optimization process the smart materials are not preferable for wide range industrial use. Though smart materials are considered expensive, complicated and clumsy, an overall view of the entire system can show the real benefits. This forms a challenge for both designers and developers of smart materials so that the total blessings of smart materials are realized.[2]

**Prof. Parihar A.A.** et.al tells us about mechanical, etc and environmental modifications and activate their operation according to these changes are smart materials. Smart materials nowadays are in limelight across the world, this popularity is due to the number of research carried out to apply these materials in technology, engineering applications and most importantly to bring this useful to common man. A wide variety of smart materials exist which includes piezoelectric materials, magneto rheological materials (MR), electro rheological materials (ER), shape memory alloys, etc. in both ER and MR fluids, the change in fluid properties like viscosity can be manipulated by varying an electric supply, by varying the strength of the electric field, the particle change can be aligned in between the electrodes. Author conveys the applications of smart materials through this paper. The ultimate goal of research in these fields is to understand and control the composition and microstructure of smart materials. It is also essential for manufacturing high-quality smart materials. [6]

According to **Susmita Kamila** et.al Smart materials are common names for a large cluster of various substances, they are featured by the ability to alter one or more properties under controlled conditions. Author brings into consideration that the definition of smart materials has been expanded to the materials that receive, transmit, or process a stimulus and respond by producing a useful effect that may include a signal that the materials are acting upon it. This research paper focuses on the introduction of smart materials and their classifications. Smart materials have a great interlink age between various fields; it extends from basic science to applied sciences and mechanical engineering to aeronautical engineering. Despite having numerous researches in smart materials, their application in engineering is not considerable. Today smart materials have emerged as the most promising technology due to its reliability and efficiency.[3]

**Keshav Sharma** et.al says, as we are heading towards a world of automation and artificial intelligent, author says, the need of "smart materials" which have capacity to sense its environment and the effects thereof have increased. Smart materials are new generation materials which suppresses the customary primary and practical materials. Beginning from the field of fundamental science like physics, mechanics, chemistry it also covers the applied sciences and designing like aerospace and mechanical designing. Smart materials are also called as intelligent materials, are designed materials that have one or more properties that can be significantly changed. Author emphasizes that these materials are acquiring significance in numerous industries including aviation. It is because of a direct result of these materials like self-sensing, self-flexibility, memory capabilities. These materials have capacity to work in multifunctional ways these materials have an increasingly important role in shaping a better future. May be materials are not just getting smart, but "alive" as well and it will change the way of our livings. Now-a-days Eco-friendly

smart materials are developed for reducing the harmful effects. These materials have an extraordinary significant task to carry out in shaping the world around us, regardless of whether that's aerospace or the clothes on our back. According to the author it is one of the keys to making a better designed world around us.[7]

**Ibrahim NazemQADER** et.al emphasizes about smart materials. Accordingly, Smart materials are the materials that respond to the environmental changes and then undergo a material property change. They are characterized by their reactions, such as physical (pressure, temperature, moistness, light, electric field, attractive field), synthetic (pH, etc). Most particularly, Smart materials innovation enables us to adjust to ecological changes by activating its functions. These materials can also be called as responsive materials as it can be transformed into new shapes because of their reactive nature. Although all smart materials are important but few of them are standing out enough to be noticed among due to their vast application in sensitive sector. Because of various reactions to natural boosts. These materials are classified into different categories such as piezoelectric materials, electrostrictive materials, magnetostrictive materials, chromic materials, etc. On other hand, talking of the advantages of these materials they are self-convenience with their current circumstance, consume less energy as well. They can give different feature for any composition and adding new additives. Thus, there are an extremely different ways for investigation in either experimental or theoretical applications.[8]

**Brian Sandarset** et.al explains about use of smart materials in defence and research project agency. The author has investigated on smart rotor project application of new actuation schemes for application of helicopter. The main objective behind this was to demonstrate the feasibility of smart material controlled secondary actuation of helicopter. Accordingly to the author, the demonstration project have opened door for more innovative thinking in shape control and capabilities enabled them. A glimpse of what is possible with advancements in shape control for air vehicles are with jointly funded air force research laboratory (AFRL) and NASA mission adaptive wing (MAW). Smart materials and structures technology combined with insight gained from this projects and programs described above offer the potential to design wing with time variant, controlled geometry. In this age of simulation based research and development, advancements in design and analysis tools that take new notions should be developed. [9]

**AlArshBasheer** et.al highlights about smart materials. Accordingly, Smart materials also called smart materials are gaining importance continuously in many businesses including outer space one. It is because of the nothing else in the world features of these materials such as self-sensing, self-ability to change, memory abilities and manifold functions. It is carefully thought about or believed worthwhile to write a review on this subject. This describes the advances in smart materials about their uses in outer space businesses. The classification, working way of Nano-smart materials are discussed. Besides, the future opinions, points of view of these materials are also highlighted. The development of smart materials is a combined area. The manufacturing of the Nano-smart materials and understanding of the working way will improve the properties and applications in outer space businesses. The

nano-smart materials will be highly useful in our space missions.[10]

**DrAyman El-Fatetry** et.al emphasizes about smart materials. Accordingly, the possible opportunities promised by nanotechnology for enabling advances in defence technologies are huge. Although these opportunities are likely to be made real over about twenty, many advantages are now being secured, especially for defence uses. This review will provide understanding of the abilities offered by nanotechnology which will enable new defence abilities, including smart materials, some platforms, new fuel sources and storage as well as novel medical computer. Basically, the current time of moving ahead in the field of nanotechnology will affect all apart of defence applications and the vision is slowly being achieved through real commercial success. Dr. Ayman El-Fatetry et.al author emphasizes about smart materials. Accordingly, the potential opportunities promised by nanotechnology for making able to moves in way to keep safe in defence technologies are somewhat difficult to believe. Although these opportunities are likely to be realized over a few decades, many advantages are currently stuff explored, particularly for defence applications. This review provides little bit capabilities offered by nanocomposites which include smart materials, some platforms, new fuel sources and storage as well as novel medical applications. It discusses polymer-based nanocomposites materials, nanoscale fillers and provides examples of the very and potential uses of nanocomposites materials in defence with practical examples the commercial impact may include inkjet markets, nanoparticles in cosmetics, and automotive applications such as soul moldings, engine covers and catalytic converts, batteries, computer chips, memory devices, biosensors for diagnostics, advances in lighting are all possible.[11]

### Conclusion:

All smart material play vital role in their sector, while few of them get importance due to their research. India is a developing country; it has started research in field of nano-technology and smart material from a decade ago. These smart materials will strengthen the defence forces. These materials cover the field starting from basic science to field of medical and engineering. With the development in technology, the next generation aircraft will be operated according to the requirement. Though there are restriction regarding smart materials, but these materials have proven themselves the best. Understanding and controlling the structure and microstructure of any new materials are definitive goals of examination in this field and is vital to the creation of smart materials.

### Reference:

- [1] Levy, T.E., et al., Early Bronze Age metallurgy: a newly discovered copper manufactory in southern Jordan. *Antiquity*, 2002. 76(292): p. 425-437
- [2] Lloyd, PA (2007) Requirements for smart materials. *Proceedings of the Institution of Mechanical Engineers, Part G: Journal of Aerospace Engineering* 221: 471-478.
- [3] Kamila, S., 2013. Introduction, classification and applications of smart materials: an overview. *American Journal of Applied Sciences*, 10, 876-880

- [4] Sagar P. Hubballi et.al, A review on introduction, classification and applications of smart materials (Volume 8, Issue IX)
- [5] R. V. Kurahatti, A.O. Surendranathan., et.al ., Defence Applications of Polymer Nano-composites Defence Science Journal, Vol. 60, No. 5, September 2010, pp. 551-563
- [6] Prof. Parihar A. A, Ms. Kajal D. khandagale, Ms. Pallavi P. Jivrag, IOSR- JMCE, e-ISSN: 2278-1684,p- ISSN: 2320-334X, Volume 13, Issue 5 Ver. VI, PP 28-32, Sep. - Oct. 2016
- [7] K. Sharma and G. Srinivas, Flying smart: Smart materials used in aviation industry, Materials Today: Proceedings, <https://doi.org/10.1016/j.matpr.2019.10.115>
- [8] Qader, İ, Kök, M, Dagdelen, F, Aydoğdu, Y. "A review of smart materials: researches and applications". El-Cezeri Journal of Science and Engineering 6 (2019 ): 755-788
- [9] Brian Sanders, Robert Crowe and Ephraim Garcia. Journal of Intelligent Material Systems and Structures 2004, DOI: 10.1177/1045389X04042793
- [10] Basheer, A. A. (2020), "Advances in the smart materials applications in the aerospace industries", *Aircraft Engineering and Aerospace Technology*, Vol. 92 No. 7, pp. 1027-10352004, DOI:10.1177/1045389X04042793
- [11] El-Fataty, A. (2007) Defence Applications. In Nanotechnology Aerospace Applications – 2006 (pp. 6-1 – 6-6)

